The Cost Impact of Biogas Siloxane Contamination
BIOGAS SILOXANE DAMAGE
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[Map showing locations around the world with red markers]
Every day, BIOGAS used for power generation robs the user of $100’s of dollars due to improper gas treatment.
Starting point:

Comprehensive gas analysis.
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Siloxane Gas Sampling Train
Biogas sampling methods for VOCs
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Comprehensive Gas Analysis

• Key to Proper Treatment System Design
• Benchmark of Gas Composition
• Basis for Optimization and Troubleshooting
What are siloxanes?
Siloxanes are organosilicons added to many personal care products and are present in almost all biogas.

Typical levels are:
- Landfills – 0.5 to 50 ppm v/v
- Digesters – 0.5 to 140 ppm v/v
Hexamethyldisiloxane Chemical Formula

\[ \text{CH}_3 \text{Si} - \text{O} - \text{Si} \text{CH}_3 \]

MM
Most common Siloxanes encountered in digester and landfill gases:

- MM (Hexamethyldisiloxane)
- MDM (Octamethyltrisiloxane)
- D$_3$ (Hexamethylcyclotrisiloxane)
- D$_4$ (Octamethylcyclotetrasiloxane)
- D$_5$ (Decamethylcyclopentasiloxane)
- D$_6$ (Dodecamethylcyclohexasiloxane)
Removal of siloxanes can save a 5 MGD WWTP $60,000 to $130,000 per year
• in operating costs.
Deposits are formed containing mostly silica and silicates (SiO$_2$ and SiO$_3$), and can also contain aluminum, calcium, copper, iron, magnesium, sodium, sulfur, and zinc.

- Silicon: 42.2%
- Oxygen: 33.3%
- Calcium: 18.5%
- Sulfur: 3.2%
- Iron: 2.8%
A 1MW engine burning digester gas with just 1 ppmv of Siloxane D5 can generate enough silicon dioxide in one year to nearly fill 2 x 100 lb. bags.
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Silicon Deposits on Cylinder Walls and Pistons
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Silicon dioxide deposits
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Erosion
Silicon dioxide deposits in a valve seat
Silicon dioxide deposits in a turbocharger
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Turbine Impeller Blade Erosion
Some Typical Savings

- **Spark Plugs** ➔ Increase Life 4x to 5x
- **Engine Re-Builds** ➔ Go from 6,000 to 30,000 hours
- **Boiler Re-Tube** ➔ Increase Life by 300% to 400%
- **SCR Catalyst Bed** ➔ $10,000 to $1,000,000
- **Power Savings** ➔ From 75% to 98%+ on-line
- **Oil Changes** ➔ Go from 500 to 2,500+ hours
Silicon dioxide deposits in a boiler
Boiler tube fouling by silicon dioxide
<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
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<tbody>
<tr>
<td>Head Life</td>
<td>7,400 hours</td>
<td>14,000 to date</td>
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<tr>
<td>Oil Changes</td>
<td>600 hours</td>
<td>3000 hours</td>
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<tr>
<td>Oil Ash</td>
<td>125 + ppm</td>
<td>5-8 ppm</td>
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<tr>
<td>Sulfur (H₂S)</td>
<td>600-1600 ppm</td>
<td>&lt; 10 ppm</td>
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<tr>
<td>CO &amp; NOx</td>
<td>Net Reduction</td>
<td>38 to 45%</td>
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<tr>
<td>On-Line Time</td>
<td>64%</td>
<td>98%</td>
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BIOGAS SILOXANE DAMAGE
### Santa Cruz, CA

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
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<tbody>
<tr>
<td>Head Life</td>
<td>8,000</td>
<td>30,000 +</td>
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<tr>
<td>Oil Changes</td>
<td>250 hours</td>
<td>2500 hours</td>
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<tr>
<td>Oil Ash</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>Sulfur (H₂S)</td>
<td>30 ppm</td>
<td>&lt; 1 ppm</td>
</tr>
<tr>
<td>CO &amp; NOx</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>On-Line Time</td>
<td>55%</td>
<td>98%</td>
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</tbody>
</table>
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Santa Cruz, CA
Stockton, CA

Head life increased from 8,000 hours to 25,000 hours

Savings = $136,000
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Stockton, CA
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SAGPack™ System

- Chiller
- Exchangers
- Compression
- System Inlet
- Coalescer
- Blending/Recycle
- Silencer and Mixer
- System Outlet
- SAG Vessels
BIOGAS SILOXANE DAMAGE

European H$_2$S Removal System
### Mangere, NZ

<table>
<thead>
<tr>
<th>Area of Savings</th>
<th>Savings ($NZ / Year)</th>
<th>% of Total</th>
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</thead>
<tbody>
<tr>
<td>Engine O &amp; M</td>
<td>$350,000 to $450,000</td>
<td>55% to 60%</td>
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<tr>
<td>Spark Plugs</td>
<td>$135,000 to $175,000</td>
<td>20% to 25%</td>
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<tr>
<td>Natural Gas</td>
<td>$120,000 to $160,000</td>
<td>15% to 20%</td>
</tr>
<tr>
<td>Oil</td>
<td>$45,000 to $65,000</td>
<td>5% to 10%</td>
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SAGPack™ Process for Moisture and Siloxane Removal
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